USE OF GAS GENSETS IN STANDBY APPLICATIONS
INTRODUCTION

- **Paul Zink**
  - Caterpillar Inc.
  - EP Gas Account Manager
  - 28 Years with Caterpillar
  - 15 Years in Customer Service and Sales
  - 10 years in Electric Power Gas Sales
AGENDA

• Emergency power supply gas generator sets
• Why gas generator sets in standby applications?
• Differences between diesel and gas generator sets
• Applications for gas standby generator sets beyond emergency
• Maintaining gas generator sets for highest reliability
EMERGENCY POWER SUPPLY
GAS GENERATOR SETS
MARKET NEED ADDRESSED BY GAS EMERGENCY POWER SUPPLY GENERATORS

TARGETED APPLICATION:
- Emergency Standby
- Legally Required Standby
- Optional Standby Systems

BACKUP POWER FOR:
- Office Buildings / Complexes
- Industrial Facilities
- Data Centers
- Retail Complexes
- Schools
- Government Buildings
- Universities
- Research Facilities
- Many Other Applications

OPERATING HOURS:
- Generator Exercising: ≤ 100 Hrs/Year
- Indefinite / Duration of Outage

LOAD PROFILE CHARACTERISTICS:
IN EVENT OF POWER OUTAGE
- Varying Load for Duration of Outage (50–100%)

CRITICAL CUSTOMER REQUIREMENTS:
- Performance Reliability
- NFPA110 Level 1 Type 10 Compatible
- High Level Transient Response Capability
- EPA Certification
- CSA Certification
- UL2200
CERTIFICATION, STANDARDS, AND REGULATIONS

Genset:
- UL 2200 (Low Voltage Only)
- NFPA110 Level 1 Type 10 Capable
- NFPA 37
- NFPA 70
- CSA 282-00 (Low Voltage Only)
- CSA B149.3
- CSA Class 4215 01
- ISO 8528-1
- ISO 8528-5
- ISO 9001
- EPA Certification

Engine:
- ISO3046
- ISO8528-2
- ISO 8528-3

Generator:
- NEMA MG1
- UL 1446
- IEC 60034 (IP-22)
- MIL 461-C
- CSA 22.2
**CAT® NATURAL GAS GENERATORS ARE DESIGNED TO MEET ALL TECHNICAL REQUIREMENTS OF THE STANDBY MARKET**

<table>
<thead>
<tr>
<th>COMMON REQUIREMENTS FOR STANDBY NATURAL GAS GENERATORS</th>
<th>REQUIREMENT DETAIL</th>
<th>HOW CATERPILLAR MEETS THESE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFPA 110</td>
<td>Must provide voltage and frequency acceptable to connected load (at transfer switch load terminals) (i.e.: 10 seconds for level 1 type 10 applications)</td>
<td>Caterpillar generators are capable of being ready to accept full load in 10 seconds and running continuously for the duration of the outage.</td>
</tr>
<tr>
<td>POWER REQUIREMENTS</td>
<td>Flexibility in the product offering to cover specific needs of the end-user</td>
<td>Natural gas ratings from 30 kW to 9,700 kW</td>
</tr>
<tr>
<td>SOUND ATTENUATION*</td>
<td>Ability to meet decibel requirements on-site during operation of the generator</td>
<td>Patten Power has engineers and strategic partners to ensure unique sound requirements are met</td>
</tr>
<tr>
<td>TRANSIENT RESPONSE</td>
<td>Ability to meet desired transient capabilities (G1, G2, ISO 8528-5 load steps)</td>
<td>Caterpillar systems minimize voltage and frequency deviation and time to recover for your operations</td>
</tr>
<tr>
<td>NFPA 37</td>
<td>Consideration for fire protection and safety of installation</td>
<td>Gas train is designed to comply with safety requirements</td>
</tr>
<tr>
<td>CSA B 149.3</td>
<td>Consideration for fire protection and safety of installation</td>
<td>Gas train is designed to comply with safety requirements</td>
</tr>
</tbody>
</table>

*Sound requirement capabilities are supplier specific*
WHY GAS GENERATOR SETS IN STANDBY APPLICATIONS
WHY NATURAL GAS IN STANDBY?

- Fuel Availability
  - Diesel supply can be weak link under certain conditions
- No Diesel Storage Tank
- Emissions
  - High availability of gas
  - Low risk of fuel contamination
- Application Flexibility
WHY NATURAL GAS IN STANDBY?

- Code requirements limit or restrict diesel storage in some instances / areas
- No fuel treatment required

Fuel Availability

No Diesel Storage Tank

Emissions

Application Flexibility
• Considered on-site storage in many instances
• Strong pipeline infrastructure with storage and few single points of failure.
• Superior run time capability compared to diesel
• Supported by DOD/MIT study

WHY NATURAL GAS IN STANDBY?

Fuel Availability
No Diesel Storage Tank
Emissions
Application Flexibility

• G3512 at 750 and 1000kW is EPA Certified for Emergency Applications
• Cat® Gas Generator Sets meet NSPS without aftertreatment
  – Emissions limits for emergency applications
    • \((2g/bhp-hr \text{ NO}_x, 4g/bhp-hr \text{ CO}, 1g/bhp-hr \text{ VOC})\)
  – Local codes may require lower emissions
  – Many emissions settings available at or below 1g/bhp-hr \text{ NO}_x without aftertreatment
WHY NATURAL GAS IN STANDBY?

- Fuel Availability
- No Diesel Storage Tank
- Emissions
- Application Flexibility

• Fuel cost savings with gas
  – For 100 hrs of operation at 1.5 MW, fuel cost savings approach $34,000 *

• Demand response viable
  – For non-life safety applications
  – When equipped for continuous duty

* Comparison based on a G3516C ($4.5/mmBtu) vs. 3512C ATAAC ($3.87/gal)

Duck graph courtesy of CAISO (caiso.com)
EMERGENCY POWER SUPPLY GENSETS

Example Loads:
- Egress Lighting
- Elevators
- Fire Detection / Alarm
- Fire Pumps

Equipment Protecting People Leaving a Building ≤10 Seconds Without Power
Emergency Systems

Example Loads:
- Egress Lighting
- Elevators
- Fire Detection / Alarm
- Fire Pumps

≤ 10 Seconds Without Power

Equipment Protecting People Leaving a Building

Legally Required Standby

Example Loads:
- Communications Equipment
- Smoke Removal Equipment
- Ventilation
- Sewage Removal Systems
- Industrial Equipment (Safety)

≤ 60 Seconds Without Power

Equipment Aiding Rescue Workers & Mandatory Building Functions

NEC:
Shall not be solely reliant on public fuel source (gas line) for fuel supply unless acceptable to AHJ
Emergency Systems

Example Loads:
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Legally Required Standby

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≤10 Seconds Without Power

Equipment Aiding Rescue Workers & Mandatory Building Functions
≤60 Seconds Without Power

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unless acceptable to AHJ

Optional Standby Systems

Example Loads:
- Data Equipment
- Refrigeration Equipment
- Optional Lighting
- Industrial Equipment
- Other not legally required applications

Does Not Protect People, Protects Business
Undefined Time Without Power
TRANSIENT RESPONSE

TRANSIENT LOAD PERFORMANCE AND ACCEPTANCE FOR A G3512 STANDBY – 1000 kW – WITH FAN

Source: Caterpillar data sheet EM1506-01-E
G3512 QUICK START VIDEO

COLD START: RAMP TO 100 % LOAD
DIFFERENCES BETWEEN DIESEL AND GAS PRODUCTS

Diesel Generator Set

Gas Generator Set
# DIESEL VS GAS ENGINES: HOW ARE THEY THE SAME?

<table>
<thead>
<tr>
<th>System</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>Nearly identical</td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>– 4 stroke cycle</td>
<td>Same</td>
</tr>
<tr>
<td>– Air intake systems</td>
<td>Same</td>
</tr>
<tr>
<td>– Exhaust systems</td>
<td>Same</td>
</tr>
<tr>
<td>– Cooling systems</td>
<td>Similar two-circuit systems</td>
</tr>
</tbody>
</table>
Diesel vs Gas in Standby Applications

- Diesels in general accept transient load better than gas (specifically larger load steps)
- Some Diesel models start faster than gas
- Steady state stability is typically better with diesel
- Some gas engines accept load better than others
  - Some gas engines are specifically designed for standby applications where their performance is similar to diesels.
  - Less efficient engines accept load better than high efficiency engines
- Other contributing factors
  - Gas pressure, temperature, air restrictions
DIESEL VS GAS RATINGS

• Diesel engine ratings
  – Rating limits structural
  – Increased rating, increased engine wear
  – Standby, Prime, and Continuous ratings
    • Ex: 3516C-HD 2500 / 2250 / 2050

• Gas engine ratings
  – Rating limits are thermal
  – Same rating for standby, prime, and continuous
  – No overload capability
### CAT DIESEL STANDBY RATING DEFINITION

<table>
<thead>
<tr>
<th></th>
<th>Emergency Standby Power (ESP)</th>
<th>Standby Power (SP)</th>
<th>Mission Critical Power (MCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability</strong></td>
<td>Varying load for duration of emergency outage</td>
<td>Varying load for duration of normal source interruption</td>
<td>Varying load for duration of normal source interruption</td>
</tr>
<tr>
<td><strong>Average output</strong></td>
<td>70% of ESP rating</td>
<td>70% of SP rating</td>
<td>85% of SP rating</td>
</tr>
<tr>
<td><strong>Typical operation</strong></td>
<td>50 hrs/yr</td>
<td>200 hrs/yr</td>
<td>200 hrs/yr</td>
</tr>
<tr>
<td><strong>Maximum expected</strong></td>
<td>200 hrs/yr</td>
<td>500 hrs/yr</td>
<td>500 hrs/yr</td>
</tr>
</tbody>
</table>
# CAT GAS STANDBY RATING DEFINITION

<table>
<thead>
<tr>
<th></th>
<th>Standby Power (SP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability</strong></td>
<td>Varying load for duration of normal source interruption</td>
</tr>
<tr>
<td><strong>Average output</strong></td>
<td>70% (capable of running continuously at 100% of nameplate rating)</td>
</tr>
<tr>
<td><strong>Typical operation</strong></td>
<td>200 hrs/yr</td>
</tr>
<tr>
<td><strong>Maximum expected</strong></td>
<td>500 hrs/yr</td>
</tr>
</tbody>
</table>
## SUSTAINABILITY AND EMISSIONS

<table>
<thead>
<tr>
<th>Diesel</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required NOx for Emergency Use</strong></td>
<td><strong>Required NOx for Non-Emergency Use</strong></td>
</tr>
<tr>
<td>NOx</td>
<td>6.4 g/bhp-hr</td>
</tr>
<tr>
<td>No SCR</td>
<td>Requires SCR</td>
</tr>
<tr>
<td><strong>Required NOx for Emergency Use</strong></td>
<td><strong>Required NOx for Non-Emergency Use</strong></td>
</tr>
<tr>
<td>NOx</td>
<td>2 g/bhp-hr</td>
</tr>
<tr>
<td>No SCR</td>
<td>No SCR (oxy cat maybe required)</td>
</tr>
</tbody>
</table>

SCR = Selective Catalytic Reduction, Increases CapEx and OpEx

*Today’s natural gas engines can run down to 0.5g/bhp-hr NOx with no SCR
GENERATOR RATING LEVELS

• Generators are rated based upon the service they are designed/expected to deliver.

• Gas uses the same design criteria as diesel

<table>
<thead>
<tr>
<th>Generator Class</th>
<th>Temperature Rise °C</th>
<th>Genset Package Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>80</td>
<td>Continuous</td>
</tr>
<tr>
<td>H</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>F</td>
<td>105</td>
<td>Prime</td>
</tr>
<tr>
<td>H</td>
<td>125</td>
<td>Prime</td>
</tr>
<tr>
<td>F</td>
<td>130</td>
<td>Standby</td>
</tr>
<tr>
<td>H</td>
<td>150</td>
<td>Standby</td>
</tr>
</tbody>
</table>
APPLICATIONS FOR GAS STANDBY GENERATOR SETS BEYOND EMERGENCY
KEY DEMAND RESPONSE MARKET DRIVER: SPARK SPREAD

Source = US DOE Energy Information Administration
DEMAND RESPONSE MARKET

Target Application: Load Management - Peak Shaving
- 100% load factor
- 500 – 4000+ hours per year
- Hours limited by spark spread

Peaking Power For:
- Commercial facilities
- Shopping centers
- Industrial facilities
- Data centers
- Government buildings
- Universities
- Utilities
- Etc.
DEMAND RESPONSE MARKET

Target Application: Load Management - Peak Shaving

Critical Customer Requirements:

- Fuel efficiency is more important than for emergency standby
- Required efficiency is driven by gas price and number of operating hours
- Performance reliability
- Maintenance and overhaul costs
- Project pro forma
- 1g/hp-h NO$_x$, 2g/bhp-h CO, 0.7g/bhp-h VOC
## PEAK SHAVING COMPARISON

<table>
<thead>
<tr>
<th>Diesel</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>• New installations are Tier 4</td>
<td>• Minimal aftertreatment</td>
</tr>
<tr>
<td>• Less than 100hrs per year</td>
<td>• Low operating costs</td>
</tr>
<tr>
<td></td>
<td>• Up to 3000 hrs per year</td>
</tr>
</tbody>
</table>
INVERSE OF CRITICAL CUSTOMER REQUIREMENTS (CCRs) FROM STANDBY TO CONTINUOUS DUTY

**CCRs – EP Standby**
- Load Response
- Start-To-Load Time
- Price
- Power Density

**CCRs – EP Continuous**
- Efficiency
- Durability (8000+ hr/yr)
- Fuel Tolerance

- Efficiency
- Durability (8000+ hr/yr)
- Fuel Tolerance

- Load Response
- Start-To-Load Time
- Price
- Power Density
LOWER OPEX WITH NATURAL GAS

- Fewer maintenance intervals with gas
- Gas fuel consumption better than diesel
- Fuel cost in favor of natural gas
Natural gas engines have the ability to provide utility peaking capabilities and system standby.
CAT GAS PACKAGES

- Packaged generator sets designed to meet site requirements
- Modules are transportable
- Similar in concept to power module
MAINTAINING GAS GENERATOR SETS FOR HIGHEST RELIABILITY
MAINTAIN SYSTEMS FOR HIGHEST RELIABILITY

• Long term system reliability is dependent upon a rigorous preventative maintenance plan.
GENERAL MAINTENANCE CONSIDERATIONS

Common causes of failure to start:

- Discharged batteries
- Not in Auto/E-stop
- No fuel/bad fuel
- Low fluid levels/filter contamination
CONDITION MONITORING

“Processes that facilitate timely and accurate detection of changes in equipment health, operation and application severity in support of a repair before failure maintenance strategy.”
CONDITION MONITORING

• Understand the monitored process
• Normalized readings
• Focus on changes occurring over time and trend
• End State: Scheduled repairs instead of unplanned downtime
DESIGNED FOR SERVICE AND MAINTENANCE

• Cat product designs
  – Match power need and equipment capability
  – Make equipment quick and easy to service

• Cat dealer maintenance plans
  – Needed for any long term outage
  – Cover all scheduled maintenance

• Disaster preparedness plans
  – Rental equipment contingency
  – Quick coupling – rental genset and load bank
  – Equipment right of first refusal

Generator Quick-Connect Box
# MAINTENANCE FOR STANDBY GENERATOR SETS

## Diesel Generator Sets
<table>
<thead>
<tr>
<th>Maintenance Item</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil change</td>
<td>250-300</td>
</tr>
<tr>
<td>Top end</td>
<td>8-10k</td>
</tr>
<tr>
<td>Overhaul</td>
<td>18-20k</td>
</tr>
</tbody>
</table>

## Gas Generator Sets
<table>
<thead>
<tr>
<th>Maintenance Item</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil change</td>
<td>2000-4000</td>
</tr>
<tr>
<td>Spark plugs</td>
<td>2000-4000</td>
</tr>
<tr>
<td>Top end</td>
<td>20k</td>
</tr>
<tr>
<td>Inframe OH</td>
<td>40k</td>
</tr>
<tr>
<td>Major OH</td>
<td>80k</td>
</tr>
</tbody>
</table>

* Service intervals at B10 service life
REGULAR, PERIODIC, AND ANNUAL MAINTENANCE

- What we typically think of as preventive maintenance
- Document and trend data for future reference
- Follow the manufacturer’s recommended maintenance interval schedule, especially for standby units.
- Follow predictive maintenance procedures for peaking units.
REPAIR RISK MANAGEMENT IS IMPORTANT TO CONTROLLING COSTS

• Schedule repairs per service manual intervals
• Schedule predictive monitoring tasks
  o Valve recession, blow-by measurements, oil consumption, fuel consumption, exhaust emissions, etc.
  o Predictive monitoring can reduce service cost by up to 15%.
ESTIMATED MAINTENANCE COST VS. LOAD FACTOR

Cost

Hours

Maintenance @ 100% Load Factor
Maintenance @ 85% Load Factor
Caterpillar and its worldwide dealer network bring a depth of experience to the natural gas standby market

Caterpillar is the world’s leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial turbines and diesel-electric locomotives.

A global reach that is unmatched
- $47B in global revenues
- Serving 182 countries through 178 dealers worldwide
- $1B+ global annual rental sales
- Nearly 90 years of engineering experience

The best rental power network in the region
- Over 1,000 locations from 52 dealers
- 3.3 gigawatts of power
- 100,000 tons of cooling
- 1.8 million cfm of compressed air

Patten Power Systems is the Greater Chicago Region Dealer for CAT Equipment and we are available to serve and support you from the simplest to the most complex project.

Electric power solutions & expertise
- 100 kW to 9700kW Diesel or Natural Gas generator sets
- CAT Paralleling Switchgear – Low voltage to 15kV class
- Flywheel UPS
- Sales, Application Engineering, Project Management, Product Support and Service Groups.

The best rental power network in Chicago metro and Northern Illinois
- Over 160 units in the Patten Power Systems rental fleet
- Young rental fleet (less than 750 hours in average on each unit)
- 15 kW to 2000 kW single units
- Access to Global CAT Rental Network

Built for it.
STANDBY RATINGS

GAS GENERATORS 60 Hz Standby Gas Ratings

<table>
<thead>
<tr>
<th>Model</th>
<th>750-2000 kW</th>
<th>150-500 kW</th>
<th>150 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>G3500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G3400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DG30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model G3412: 350 kW to 500 kW
Model G3512: 750 kW or 1,000 kW
Model G3516C 1,000 kW to 1,500 kW
Model G3520C 1,500 kW to 2,000 kW
SUMMARY

The demand for gas standby power is growing rapidly
- Local codes may favor gas for standby (diesel fuel storage/environmental concerns)
- Emissions limits: Gas products can be lower-cost than Tier 4 diesel.
- Natural gas infrastructure is robust: secure in many natural disasters.
- Gas gensets offer high reliability and long run times for peak shaving
- Cat dealers deliver excellent parts and service support
QUESTIONS?